

# Diver-Operated Instruments for In-Situ Measurement of Optical Properties

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## LONG-TERM GOALS

This work is undertaken as part of a long-term effort to document and understand the optical properties of benthic organisms and substrates. This understanding is sought as part of efforts to apply both *in-situ* and remote sensing optical measurement techniques to problems of surveying, searching, mapping, monitoring, and assessing shallow water environments.

## OBJECTIVES

The objective of this effort is to develop improved diver-operated instrumentation for making reflectance and fluorescence spectral measurements from benthic features *in situ*. The new instrument would be used in my own research, and copies of it would be made available to collaborating researchers who could benefit from its availability.

## APPROACH

This effort builds on experience gained in developing and using an earlier version of a diver-operated instrument for measuring optical properties. The Benthic SpectroFluorometer (BSF) (Mazel, 1997 and web site shown in References) was first developed in 1994 and has been incrementally modified over the succeeding years. It has proved to be a workhorse, but remains an advanced prototype that needs nurturing and special care, and is not suitable for duplication and general distribution. The approach of this project is to identify the ways in which the BSF can be improved and design a new instrument, dubbed the DiveSpec, that retains the qualities of the BSF but does not replicate its faults. A list of desired changes includes:

- Upgrade to a newer processor.
- Replace the mechanical hard disk with solid state (flash) memory. This would decrease both power consumption and the time required to store data.
- Reduce the overall size and weight.
- Make the unit more rugged to withstand routine field use, including handling on and off small boats.
- Simplify the user interface.
- Replace the 50 W fluorescence excitation light source contained inside the BSF housing with a solution that uses less power and produces less heat.
- Improve some of the measurement techniques, especially the dependence on ambient light as the illumination source for reflectance measurements.

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Like the original BSF, the DiveSpec is intended to make three kinds of measurements:

- Spectral reflectance factor; the ratio of the light reflected from a sample to the light reflected from a Lambertian surface illuminated in the same manner;
- Spectral signature, the spectrum of light reflected from a sample under ambient illumination;
- Fluorescence.

We wished to first develop two new DiveSpec prototypes for field use by our own group and by others. That experience would be expected to lead to additional design changes, which would be retrofitted as much as possible on the two testbed instruments and implemented fully in two additional working units.

Charles Mazel is providing overall project supervision and is specifying the performance characteristics and software design. Tom Vaneck (PSI) is writing much of the new software and is working with Joe Ziehler (PSI) in designing the interface electronics.

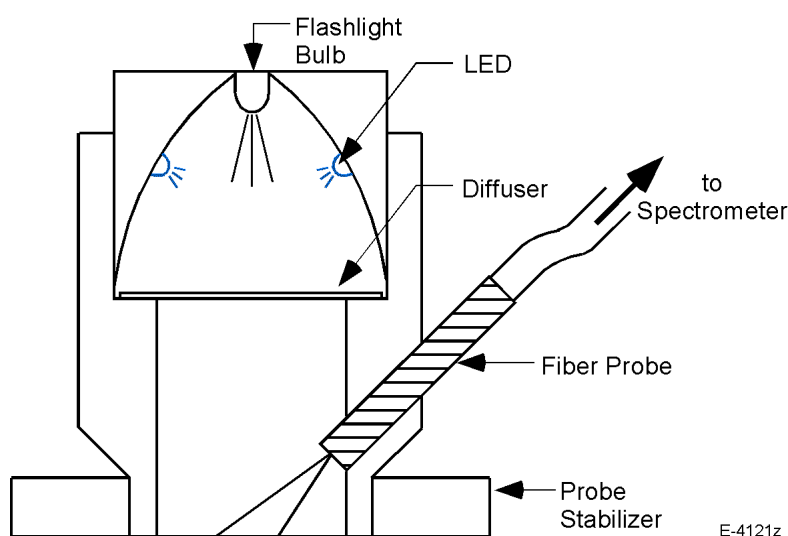
## **WORK COMPLETED**

Two prototype copies of the DiveSpec were readied in time for the Coastal Benthic Optical Properties (CoBOP) field campaign at Lee Stocking Island, Bahamas, in May/June 1999. Size and weight were reduced, compared to the BSF, by eliminating the 50 W halogen bulb source that provided excitation energy for fluorescence measurements and was contained in the BSF housing. This light source was coupled into a liquid light guide element to conduct the excitation energy to the measurement probe. The inefficiencies inherent in this approach mandated the use of a powerful bulb that required a large battery and generated considerable heat in the same housing that contained the electronics. A new probe (Figure 1) was built around a small off-the-shelf underwater flashlight. The flashlight reflector was modified to add a circular array of blue light emitting diodes (LED's) as the excitation source for fluorescence. The flashlight bulb provides a broadband illumination source for reflectance measurements. Both the bulb and the LED's are controlled by the instrument software.

We upgraded the system to a newer processor and replaced the mechanical hard disk drive with flash memory. This reduced the time it took to store the data after a measurement from approximately 25 seconds to approximately 6 seconds. This greatly increases productivity during a dive.

We replaced the glass light-collection fiber in the BSF with a custom liquid light guide. The original meter-long fiber was a weak point in the system, especially for field handling, as the fragile fiber could be snapped relatively easily. The new liquid light guide acts like an optical fiber but has no glass element to break. We solved the problem of coupling this to the spectrometer by acquiring a fiber optic pressure feedthrough that mounts in the instrument housing.

A new user interface was implemented for the DiveSpec through the creation of new software. We kept the text/graphics liquid crystal display of the original BSF, which worked very well. A new 12-element piezoelectric keypad mounted in the housing replaces the original set of six piezoelectric switches mounted on the BSF probe.



**Figure 1. Measurement probe head of the new DiveSpec instrument. The stabilizer is a removable PVC ring that adds surface area to prevent the probe from penetrating into sediments.**

Over 450 individual measurements were acquired with the DiveSpec in 13 dives during the CoBOP field campaign. The data include reflectance factor, spectral signature, and fluorescence measurements. Much fine-tuning of the software took place during this trip, and some problems with the hardware were identified and corrected.

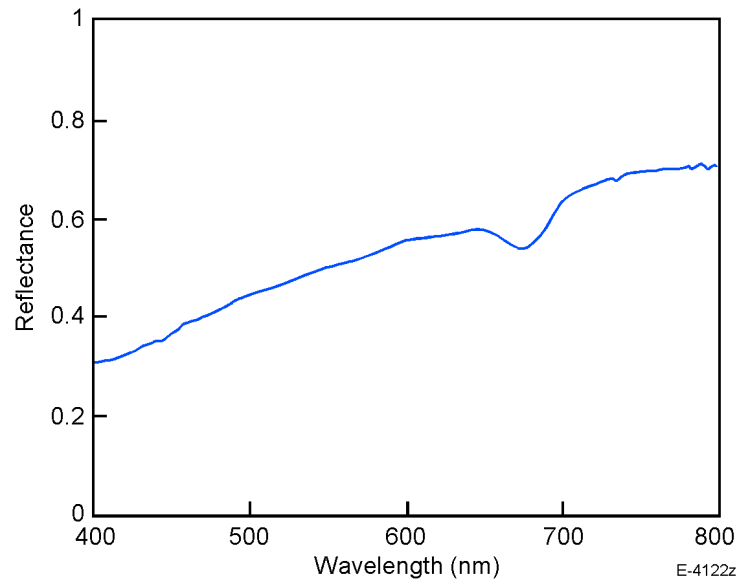
## RESULTS

The new version of the instrument is more compact than the original. Table 1 compares the physical characteristics of the original BSF and the first prototype of the new DiveSpec. The weight shown is the weight in air. Both instruments are one to two pounds negatively buoyant in salt water. We expect to reduce the size and weight even further as the design progresses.

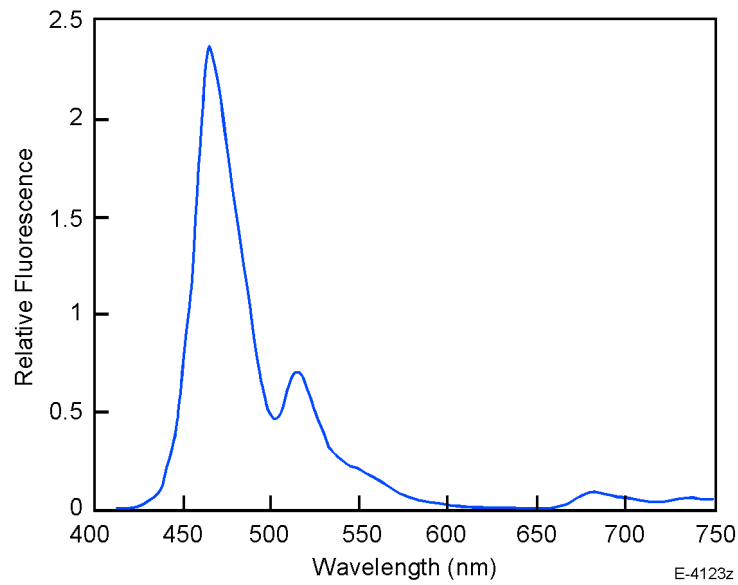
	Weight kg (lbs.)	Length cm (in.)	Width cm (in.)	Height cm (in.)
New	6.1 (13.5)	17.8 (7)	14.6 (5.75)	23.2 (9.125)
Original	12.2 (27)	26.7 (10.5)	16.5 (6.5)	23.5 (9.25)

**Table 1. Physical characteristics of the new DiveSpec and the original Benthic SpectroFluorometer.**

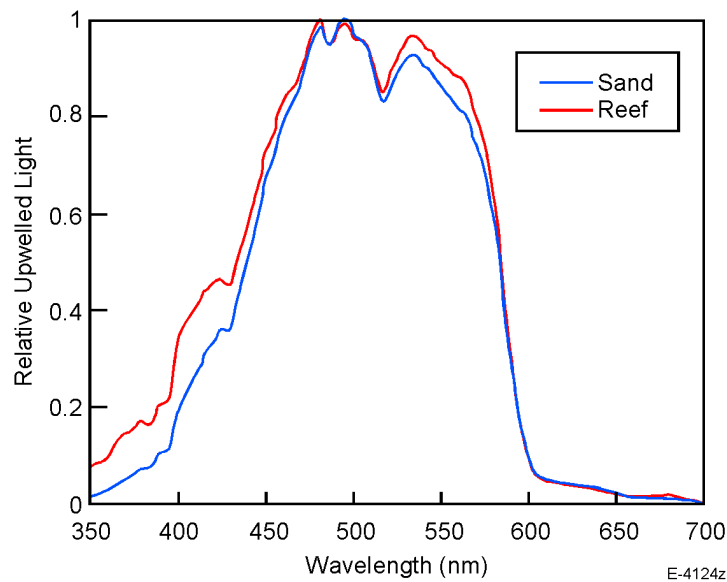
Figures 2 through 4 are example plots of the three data types. The data sets were collected in May 1999 during the CoBOP field campaign. The flashlight bulb source provides illumination covering the range of 400 to 800 nm for reflectance measurements, while the wavelength range for spectral signature measurements is governed by the available downwelling light at the measurement depth.



**Figure 2. Reflectance spectrum of sand at North Perry Reef.**



**Figure 3. Fluorescence of a colony of *Montastraea cavernosa*, Horseshoe Reef. The large peak in the blue is produced by the excitation LED's. The fluorescence peak at about 510 nm originates in the coral tissue, while the 685 nm emission is from chlorophyll in the symbiotic algae in the coral tissues.**



**Figure 4.** *Spectra of upwelling light over areas of sand (blue) and reef (red), Horseshoe Reef. The spectra have been normalized to facilitate identification of spectral differences.*

## IMPACT/APPLICATION

The new instruments are intended to advance the state of the art in diver-operated tools for underwater spectral measurements. They will provide baseline data on the spectral characteristics of benthic organisms and substrates. This data is needed as ground truth for hyperspectral remote sensing, to assist in design of specialized instruments and interpretation algorithms, and for baseline studies of the relationship between physiological state or process in marine organisms and their optical signatures. In the long run it is hoped that we will learn to interpret these signatures and the changes therein, and that optical techniques will become routine tools for seafloor monitoring, mapping, and assessment.

## TRANSITIONS

Several collaborating researchers in the ONR CoBOP and HyCODE programs will use the new instruments in their own research. The data from the first field use of the new DiveSpec is already being used in support of work done with the Naval Research Laboratory's hyperspectral imager that is being used as part of the CoBOP program.

## RELATED PROJECTS

We have been investigating the fluorescence and reflectance characteristics of seafloor substrates and organisms as part of the CoBOP program. The original BSF has been an important tool in that work, and has provided the experience needed to design the new version.

## REFERENCES

Benthic SpectroFluorometer, <http://www.psicorp.com/mazel/research/bsf/bsf.htm>

Mazel, C. H. 1997: Diver-operated instrument for in situ measurement of spectral fluorescence and reflectance of benthic marine organisms and substrates, *Opt. Eng.*, 36, 2612-2617.